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(71) Applicant: HITACHI METALS, LTD.
Chiyoda-ku, Tokyo (JP)

(72) Inventors:
- Shibata, Ryoichi
Shimotsuga-gun, Tochigi-ken (JP)
- Souda, Tomomi
Mooka-shi, Tochigi-ken (JP)
- Kaneuchi, Takao
Mooka-shi, Tochigi-ken (JP)
- Yamane, Hideya
Utsunomiya-shi, Tochigi-ken (JP)

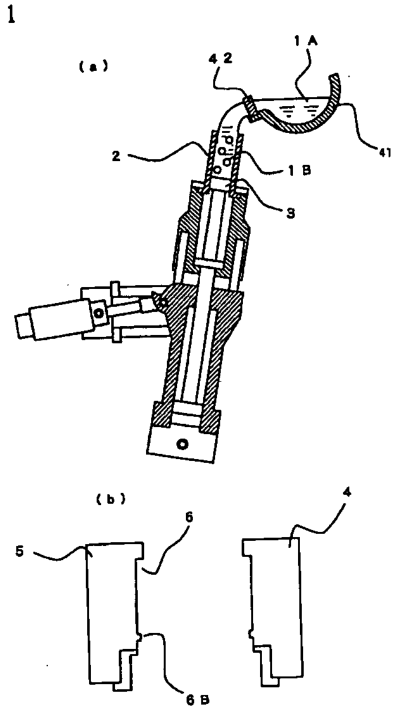
(74) Representative: Beetz & Partner
Patentanwälte
Steinsdorfstrasse 10
80538 München (DE)

(54) Die casting method

(57) The present invention relates to a die casting method in order to obtain aluminum alloy having high quality and excellent mechanical characteristics.

Further, the present invention relates to a die casting method to produce such an aluminum alloy casting, wherein primary crystal of molten metal (1A) is substantially granulated in a casting sleeve (2) so as to form a semi-molten status (1B), and then filled under pressure into a die cavity (6) and solidified, so that molten metal flow becomes laminar flow, thus making less air mixing, and casting can be made without oxides and solidified matter being filled into die cavity (6).

Fig. 1



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Description

Field of the Invention

The present invention relates to a die casting method to obtain aluminum alloy castings having high quality and excellent mechanical characteristics.

Background of the Invention

In the prior art, die casting method is well known as a casting technology to obtain aluminum alloy castings. This die casting method is a casting method to produce castings by filling molten metal in a casting sleeve into a precise metallic die cavity under pressure. According to this die casting method, there are advantages such as highly precise dimensions of castings, beautiful casting surface, availability of mass production and fully automatic production. For this reason, this method has been conventionally used mainly in the production of metal castings which have melting points below that of aluminum alloy.

However, this die casting method has had a problem that the mechanical strength of castings after casting solidification is apt to be deteriorated owing to:

1 Molten metal poured into the casting sleeve is cooled down rapidly within the inner wall of the casting sleeve, generating solidified debris, which is mixed into molten metal and cast;
2 Air in the casting sleeve is mixed into molten metal, causing blister (a phenomenon where mixed and pressurized gas inflates by thermal load to become blistering);

therefore, it cannot be applied to production of strength parts that require high strength.

In order to solve these problems, there are Special Die Casting Methods which include hot sleeve method where casting sleeve is heated in order to prevent the generation of solidified debris in the inner wall of the casting sleeve as described in the above 1, vertical die casting method which prevents air in casting sleeve as described in the above 2 from being mixed into molten metal, and the like. In addition, there is hot chamber die casting method, which is limited to the casting of zinc alloy or magnesium alloy with relatively low melting temperatures. Therefore, this method can not be applied to wide extent.

However, even in the Special Die Casting Methods mentioned above, when speed for filling the molten metal is high, molten metal in the casting sleeve becomes turbulent and catches gas, and is cooled down in the inner wall of the die cavity together with the gas, causing defect and thus deteriorating mechanical and other characteristics. In order to prevent this problem, it is necessary to make the filling speed extremely low, and in this case, insufficient flow of molten metal is caused. In addition, non-solidified portion is extracted during the development of dendrite, and segregation occurs at thick wall portion as shown in FIG.5, making mechanical and other characteristics insufficient.

Apart from the various die casting methods mentioned above, Japan Patent Publication No. H3-47951 discloses a die casting method where dies are fixed to form a cavity having a pouring gate at bottom, to which die arranged at the exit of a cylinder is connected so as to form a drawing to limit the flow of molten metal into the cavity. A port to supply molten metal from exterior is arranged at the center of the direction of central axial line of the cylinder equipped with this die, and a punch is slidably engaged, and a casting apparatus is formed. Molten metal is poured into the cylinder from the supply port, and molten metal is kept until liquid phase and solid phase become in coexisting status, then is pushed and pressed by punch through die and into cavity. According to this die casting method, the following effects are expected:

1: The molten melt can be supplied to cylinder at a temperature only just above melting point, which is relatively lower than the temperature in other methods. Therefore, energy can be saved.
2: Since the temperature of molten metal is low, gas absorption is scarce, and there is no need of degassing process, and products have few gas cavity,
3: Molten metal in a status where liquid phase and solid phase coexist without tangibleness is wholly pushed up by punch, and then subjected to plastic working in a semi-molten status while passing through the die to form drawing, and liquid phase and solid phase are mixed, and then solid phase is distracted making the casting structure fine. Thus, products with excellent mechanical characteristics can be obtained.
4: Since the molten metal is processed in a semi-molten status without tangibleness, deformation resistance is less compared with forging method, and equipment costs are reduced.

However, in this die casting method disclosed in Japan Patent Publication No.H3-47951, the structure of semi-molten metal is not granulated in the casting sleeve, so that the difference of solute concentration is large, and it is possible

that segregation occurs, as shown in variable density in FIG.6. Even when the molten metal is filled in die cavity, since its structure refinement is insufficient, there is still much to be improved in its mechanical characteristics.

Further, when the speed to fill the molten metal is fast, molten metal in the casting sleeve becomes turbulent and catches gas in, and when this molten metal is cooled down rapidly within the inner wall of the die cavity, mechanical and other characteristics are deteriorated, and castings characteristics become uneven. In order to prevent this problem, it is necessary to make the filling speed extremely low. In this case, insufficient flow of molten metal occurs.

On the other hand, with respect to automobiles, the improvement of fuel efficiency has recently become an extremely important problem from laws and regulations in the United States. From this points of view, automobile parts having light weight is sought for. Naturally, automobile parts should be sufficiently strong, and from this viewpoint, when making the weight of the parts light by having the thickness of the wall thinned, strengthening of raw material becomes an important subject.

However, since there have been problems as described above in the prior die casting method, aluminum alloy castings produced by this die casting method were too insufficient in strength to be applied for production of high strength parts such as automobile parts and the like.

Summary of the Invention

In view of the problems mentioned above, the object of the present invention is to provide a die casting method that can produce aluminum alloy castings which enables casting work with preferable molten metal flow without contamination of air, and which prevents oxides and solidified debris from being filled into the die cavity.

In order to solve the problems mentioned above, the die casting method according to the present invention is characterized by that primary crystal of molten metal is substantially granulated in the casting sleeve so as to form a semi-molten status, and is filled into a die cavity under pressure, and solidified.

In addition, in the above present invention, it is preferred to form at least part of the inner cylinder of the casting sleeve with a low thermal conductor, and to cool down the casting sleeve.

Further, in the die casting method of the present invention, it is preferred to fill the molten metal into the die cavity under pressure after having the molten metal heated by electro-magnetic stirring in the casting sleeve.

Moreover, it is preferred to make the inside of die cavity a decompressed atmosphere and/or inert gas atmosphere at least when the semi-molten metal is being filled, and to make the atmosphere of said casting sleeve interior an inert gas atmosphere.

Other objects and advantages of the present invention will become apparent from the detailed description to follow taken in conjunction with the appended claims.

Brief Description of the Drawings

In the accompanying drawings, there are shown illustrative embodiments of the invention from which these and other of its objectives, novel features, and advantages will be readily apparent.

In the drawings:

FIG. 1 is a diagram showing cross section of an important portion of a vertical die casting machine, one example to be used in the die casting method of the present invention.

FIG. 2 is a metallurgical microscope photograph showing the particle structure of semi-molten metal in casting sleeve.

FIG. 3 is a metallurgical microscope photograph showing the spherical structure of casting after filling and solidification of the molten metal in the die cavity.

FIG. 4 is a diagram showing the mechanical characteristics of aluminum alloy castings of an example of the present invention and a conventional example.

FIG. 5 is a metallurgical microscope photograph showing the structure showing segregation of casting defect.

FIG. 6 is a metallurgical microscope photograph showing the structure showing segregation occurred owing to large difference of solute concentration.

FIG. 7 is a diagram showing cross section of an important portion of a horizontal die casting machine of another example to be used in the die casting method under the present invention.

FIG. 8 is a diagram showing cross section of the portion 20 in FIG.2.

FIG. 9 is a diagram showing cross section of an important portion of a horizontal die casting machine without electromagnetic body force of another example to be used in the die casting method under the present invention.

FIG. 10 is a top view showing knuckle steering.

FIG. 11 is a top view showing insufficient flow in knuckle steering.

Detailed Description of the Invention

The invention is illustrated in further details by reference to the following referential examples and preferred embodiments wherein.

In the die casting method of the present invention, as a means to make primary crystal of the molten metal substantially granular, there is, for example, a method to lower the temperature of the molten metal in the casting sleeve from a temperature near liquid phase line to a temperature below liquid phase line and higher than solid eutectic line or eutectic line at a specified cooling speed.

Namely, in the aluminum alloy casting according to the present invention, the method to granulate primary crystal of the molten metal comprises of the following processes:

(a) process to melt metal and make its temperature near liquid phase line,
(b) process to cast said molten metal and move it to the casing sleeve, then lower the temperature of said molten metal in the casting sleeve from a temperature near liquid phase line to a specified temperature lower than liquid phase line and higher than solid phase line or eutectic line at a specified cooling speed, and to granulate the primary crystal of the molten metal substantially so as to make the molten metal into a semi-molten status,
(c) process to fill the semi-molten metal in said casting sleeve wherein the primary crystal is granulated into the die cavity under pressure, and
(d) process to solidify the semi-molten metal filled into said die cavity.

As described above, in the present invention, metal is melt and cast at a temperature near liquid phase line and then moved to the casting sleeve, so that the casting sleeve is hardly damaged by high temperature. Further, in the process to lower the temperature of said molten metal in the casting sleeve from a temperature near liquid phase line to a specified temperature lower than liquid phase line and higher than solid phase line or eutectic line at a specified cooling speed, it is not necessary to give shear such as machine stirring or electromagnetic stirring to the state where solid and liquid coexist, and primary crystal of molten metal is substantially granulated so as to form a semi-molten status, and such semi-molten metal is filled under pressure and solidified. Accordingly, casting with excellent mechanical characteristics can be obtained without occurrence of blister.

In the above mentioned die casting method, the temperature near liquid phase line is, for example, from around 10 below liquid phase line to about 40 from liquid phase line in the case of A357 alloy.

At a temperature over the range mentioned above, dendrite grows, while at a temperature below range mentioned above, dendrite occurs before pouring the molten metal.

Next, the molten metal is cooled down so as to form a semi-molten status in the casting sleeve, and then this molten metal poured into the casting sleeve in order to obtain granular primary crystal is cooled down at a specified cooling speed. It is preferable to set this cooling speed below 10/s. Thereby it is possible to granulate the primary crystal generated.

The concrete methods to cool down molten metal within a specified cooling speed are as described below:

(1) When the casting sleeve is formed by thermal conducting material such as ceramic, speed for cooling the sleeve surface is made slow, and the cooling speed in the sleeve interior is preferred to be below 10/s.
(2) In the case of metallic sleeve, it is desired to be preheated in order to raise initial temperature.
Especially, in the case when A357 material is used, the initial temperature of the casting sleeve should be set at a temperature over 200, and the cooling speed of the inner side of the molten metal is preferred to be below 10/s.
(3) The speed to cool the molten metal surface can be controlled and the interior of molten metal can be cooled down at a specified cooling speed by applying a cold clusive heating method which heats the molten metal surface by high frequency and cools the container while giving heat to the molten metal.

Additionally, in the present invention, it is preferable to make the semi-molten metal which is granulated in the casting sleeve spheric during the process of filling the semi-molten metal into the cavity. Thereby, particles become finer, and molten metal flow becomes more preferable.

In this case, it is possible to make the semi-molten metal spheric by flowing the molten metal. As a means to flow molten metal, for example, there is a means to stir the molten metal by electromagnetic force. Also, by flowing the molten metal while it is being filled into the die cavity, the structure changes from particle status into spherical status.

Additionally, in the present invention, it is possible to give thixotropy to the molten metal by controlling the solid phase rate of semi-molten metal in the casting sleeve from 30 to 60%, and thereby molten metal flow can be maintained preferably. Namely, thixotropy can be given to the molten metal by controlling the solid phase rate of semi-molten metal at over 30%, and on the other hand, by setting the solid phase rate of semi-molten metal below 60%, it is possible to prevent excessively high viscosity. Thereby, molten metal flow can be maintained preferably.

Further, in the present invention, it is preferable to form at least part of the inner cylinder of the casting sleeve by low thermal conducting material, and also to cool down the casting sleeve. Thereby, it is possible to control the cooling speed of molten metal and to make primary crystal granular. That is, by forming at least part of the inner cylinder of the casting sleeve by low thermal conducting material, it is possible to prevent heat dissipation of molten metal, and semi-molten and granular structure can be obtained without preheating casting sleeve.

The use of SIALON in the inner wall of the casting sleeve as low thermal conductor brings an effect that molten metal is hard to be wet.

Further, in the present invention, it is preferable to fill the semi-molten metal in the casting sleeve in a laminar flow status into the die cavity under pressure, and to give a higher pressure after then. Thereby, it is possible to prevent contamination of the gas into the semi-molten metal and also to prevent the occurrence of blister.

Additionally, it is preferable to make the inside of die cavity a decompressed atmosphere and/or inert gas atmosphere at least when the semi-molten metal is being filled, and to make the inner side of said casting sleeve an inert gas atmosphere. Thereby, temperature can be controlled so as to keep the material in a semi-molten status, and surface oxidation can be prevented. Accordingly, products with fine qualities can be obtained without using special method to remove surface layer.

Further, in the die casting method of the present invention, it is preferable to dispose several conducting materials to at least part of the inner cylinder of said casting sleeve, so as to form a magnetic field by the induction coil at the exterior of said conducting materials, and to lower the temperature of said molten metal in the casting sleeve from a temperature near liquid phase line to a specified temperature lower than liquid phase line and higher than solid phase line or eutectic line, and heat or keep warm and stir the molten metal, then to fill the molten metal into said die cavity under pressure.

Thereby, current is introduced by electromagnetic induction in the semi-molten material and the conductive part, and the induced current and magnetic field interacts so as to keep the molten matter away from sleeve surface, thus preventing it from contacting the casting sleeve. Therefore, temperature decrease by contact between the molten matter and the casting sleeve can be reduced, and the occurrence of solidified debris on the surface of molten metal decreases, and temperature drop of molten metal can also be reduced. Further, temperature distribution becomes uniform, and the temperature increase of the sleeve itself can be restricted, so that deformation of casting sleeve becomes smaller, and the mechanical precision of casting sleeve can be maintained.

In the above die casting method to obtain aluminum alloy casting of the present invention, thixotropy is given to molten metal, making the molten metal flow into a laminar flow so as to prevent air mixing, so that oxides or solidified debris can be prevented from being filled into the die cavity, and aluminum alloy casting with even characteristics can be obtained. The mechanism of this thixotropy is described in detail hereinafter.

When the temperature of said molten metal in the casting sleeve is lowered from a temperature near liquid phase line to a specified temperature lower than liquid phase line and higher than solid phase line or eutectic line at a specified cooling speed and the primary crystal of molten metal is substantially granulated so as to form a semi-molten status, thixotropy can be obtained by primary crystal in granular status and liquid having a temperature above eutectic temperature. Thixotropy is a nature of what is made by mixing granular solid and liquid in a certain ratio, and the phenomenon where a mixture liquidates by vibration and shear force, and solidifies when it is left alone.

In a status with such thixotropy, when force is given, there is a great tendency that molten metal flows in laminar flow compared with a complete molten metal condition, and occurrence of gas mixing while the molten is being filled from the casting sleeve into metallic die becomes scarce. Namely, when a structure becomes granular and solid phase exists at some extent, when force is given, the movement of granulated solid phase and the movement of liquid occur at the same time, and solid and liquid move together. Thereby, defects of castings become fewer, gas content decreases, and blister will not occur even at heat processing. On the other hand, when the structure is not granular, when force is given, solid phase does not move, and only molten metal between solid phases, that is, non-solidified portion appears. Therefore, segregation or air mixing occurs.

Such thixotropy cannot be obtained merely by pouring molten metal into a sleeve at low temperature; it is necessary that the structure of the molten metal is granulated, and that the solid phase rate gets high to some extent (generally over 30%). On the other hand, if solid phase rate gets excessively high (generally over 60%), viscosity increases, and molten metal flow becomes unpreferable.

Examples

Examples of aluminum alloy casting of the present invention are described in detail hereinafter.

(Example 1)

FIG.1 (a) shows a vertical die casting machine to be used in a die casting method to obtain aluminum alloy casting according to the present invention, while FIG.1 (b) shows a cross section of an important portion of a metallic die having

cavity. The pressure of the vertical die casting machine is 100MPa, and the inner diameter of the casting sleeve 2 is 50mm, while the outer diameter is 80mm. Die cavity 6 is set by upper die 4 and lower die 5, so as to cast a steering knuckle, which is a suspension part of automobile.

By use of this vertical die casting machine, aluminum alloy casting of the present invention was produced by casting A357 alloy (ASTM : A1Si7%Mg). First, A357 alloy composition is melt and heated up to the temperature around 630°C near liquid phase line (620).

Next, this A357 alloy molten metal 1A is moved by ladle 41 to a casting sleeve 2 through filter material 42 arranged at the pouring gate of ladle 41.

Then, the temperature of the molten metal is lowered in the casting sleeve 2 from a temperature near liquid phase line to a temperature around 580 °C lower than liquid phase line and higher than solid phase line or eutectic line so as to form a spherical structure as shown in FIG.2. In an A357 alloy, it is preferable to fix the cooling speed of the casting sleeve 2 from 0.5 to 8/s, and preferably 1 to 4/s. Thereby, A357 alloy molten metal 1B becomes a semi-molten status where primary crystal is granulated. As for crystal grain at this moment, the average of spherical rate (ratio of long diameter and short diameter of grain) is 0.63, and the average of circle equivalent diameter (diameter of pseudo-circle calculated from grain area) is 80Jm.

Next, semi-molten metal 1B of A357 having granular primary crystal is filled into a die cavity under pressure 6 by use of plunger 3, maintaining a laminar flow condition. Granular structure becomes finer and changes into spherical structure at gate 6B during the process of filling and pressurizing the molten metal. The structure of the molten metal after passing the gate is shown in FIG.3. The average of spherical degree (ratio of long diameter and short diameter of grain) of crystallized grain is 0.72, while the average of circle equivalent diameter (diameter of pseudo-circle calculated from grain area) is 40Jm. From Fig. 3, it is clear that after semi-molten metal structure is granulated in the casting sleeve and filled into die cavity, spherical degree (ratio of long diameter and short diameter of grain) becomes large, and circle equivalent diameter (diameter of pseudo-circle calculated from grain area) becomes small, and crystal is fine and almost circular.

The solid phase rate of semi-molten metal 1B in the casting sleeve 2 is preferred to be 30 to 60% from the condition diagram and temperature of A1-Si-Mg system aluminum alloy.
Raw material for steering knuckle can obtained by filling the semi-molten metal 1B in the casting sleeve 2 into the die cavity 6 under pressure and solidifying this molten metal, and then opening the die. Then, by heating this raw material up to a temperature around 540, segregation at casting is removed, and crystallization phase , deposition phase and the like are solved into matrix phase, and the molten metal is changed into oversaturated solid solution. And then, said oversaturated solid solution is heated up to a relatively low temperature around 160 °C, kept, and separation is facilitated by age hardening process.

Comparing the mechanical characteristics of aluminum alloy castings of the present invention obtained in the above examples with those of conventional aluminum alloy castings, the mechanical characteristics of aluminum alloy castings of the present invention showed excellent characteristics in tensile strength (A), bearing force (B), and elongation (C), as shown in FIG. 4.

The mechanical characteristics of the products formed by the aluminum alloy casting of the present invention obtained in the example described above, aluminum alloy casting of the comparative example obtained by the method of pressure forming after re-heating, and conventional aluminum alloy casting obtained by the conventional pressure forming method were compared. The results are shown in TABLE 1.

TABLE 1

	Tensile strength (N/mm^2)	Bearing force (N/mm^2)	Elongation (%)
Example	350	280	10
Comparative example (re-heating)	320	260	7
Conventional example	345	270	8

As shown in TABLE 1, the aluminum alloy casting of the example according to the present invention has excellent characteristics in both tensile strength and elongation compared with the aluminum alloy castings of the comparative example and the conventional example.

(Example 2)

Next, experiment was carried out by the same casting method as Example 1 with changed solid phase rate of semi-molten metal in casting metal. The mechanical characteristics of steering knuckle obtained through heat processing are shown in TABLE 2.

TABLE 2

Mechanical characteristics				Appearance after heat processing
Solid phase rate (%)	Tensilestrength (N/mm^2)	Bearing force (N/mm^2)	Elongation (%)	
25	329	280	1.8	With small blisters
35	347	275	8	
45	353	277	10	
55	350	282	9	
65	330	274	3.1	Insufficient flow

Semi-molten metal filled from a casting sleeve into the die cavity with solid phase rate of 25% shows small blisters and short elongation after heat processing. Therefore, it is not appropriate for steering knuckle that requires toughness.

Semi-molten metal filled from the casting sleeve into a die cavity with solid phase rate of 65% shows insufficient flow as shown in FIG.11, and therefore, cannot be applied to product. Accordingly, it is clear that in the range of 30 to 60% of solid solution rate, molten metal flow is good, only a few blisters occur, and tensile strength, bearing force, and elongation are excellent. By producing suspension part for automobiles such as steering knuckle by this die casting method, higher reliability and lighter weight can be obtained.

And when part of inner cylinder of the casting sleeve 2 is formed by a of low thermal conductor SIALON, semi-molten metal 1B is kept warm, and semi-molten granular structure can be obtained without preheating the casting sleeve 2.

Further, by decompressing the interior of the die cavity 6 during the process of filling the molten metal into the die cavity, molten metal flow is further improved, and semi-molten metal can be filled to the end of die cavity.

In addition, by supplying inert gas into the casting sleeve 2, oxidation of molten metal is prevented, and further flawless casting can be obtained.

(Example 3)

FIG.7 shows a cross section of an important part of a horizontal die casting machine to be used in a die casting method of another example of this invention, while FIG.8 shows a cross section of the portion 20 in FIG. 7. The horizontal die casting machine in FIG. 7 comprises mainly a casting sleeve 22 which comprises an outer cylinder 24 and an inner cylinder to receive molten metal 1, plunger 3 driven by a hydraulic unit, and die cavity 6 to where said plunger 3 moves to the left and fills molten metal 1 of casting sleeve 22.

In FIG. 7 and FIG. 8, the inner cylinder of the casting sleeve 22 comprises an insulator 8 formed by SIALON ceramic 23, where conductors 9 formed by discontinuous austenite stainless steel pipes are embedded discontinuously, and cooling water 11 runs through conductors 9. In place of water cooling, air cooling can also be applied, while the case of water cooling is explained in this example. By the conductor 9 and induction coil 7 of the casting sleeve 22, electro-magnetic body force is generated, and semi-molten metal in the casting sleeve is filled into the die cavity without contacting the inner wall, so that occurrence of solidified debris is limited, and temperature decrease of molten metal is small, and temperature distribution is uniform.

The pressure of the model die casting machine is 100MPa, and the inner diameter of casting sleeve 22 is 50mm, and the outer diameter is 80mm. Die cavity 6 is formed by movable die 4 and fixed die 5 so as to cast steering knuckle for automobile.

By use of this horizontal die casting machine, A357 raw material is cast in the same manner as in Example 1, and heat processing is carried out. The comparative results of the mechanical characteristics of steering knuckle produced as described above and those of steering knuckle produced by conventional low pressure casting method are shown in TABLE 3.

TABLE 3

Casting method	Mechanical characteristics		
	Tensile strength (N/mm^2)	Bearing force (N/mm^2)	Elongation (%)
Present invention	348	283	11
Comparative example (low pressure casting)	320	270	3

From the example of the present invention shown in TABLE 3, it is understood that molten metal flow is good, blisters are few, and steering knuckle with superior tensile strength, bearing force, and elongation can be obtained compared with the comparative example of conventional low pressure casting method. By producing suspension part for automobiles knuckle by this casting method, higher reliability and lighter weight can be obtained.

According to the characteristics of casting part to be produced, die casting machine shown in FIG.9 may be used in place of the die casting machine explained in this example.

The die casting machine shown in FIG. 9 comprises mainly of casting sleeve 30 to receive molten metal 31 poured from ladle 37, die cavity 36 formed by an upper die 34 and lower die 35, and plunger 33 to charge the molten metal in the casting sleeve into the die cavity.

As described above in detail, in the die casting method of the present invention, primary crystal of molten metal is substantially granulated in the casting sleeve so as to form a semi-molten status and then filled into the die cavity under pressure and then solidified, so that molten metal flow becomes a laminar flow. Therefore, air mixing is few, and casting can be produced without oxides and solidified matter being filled into die cavity. The aluminum alloy casting obtained by such a die casting method has excellent mechanical characteristics, and its characteristics are uniform, and therefore, it can be preferably applied to high hardness portions such as suspension unit including steering knuckle and aluminum wheel of automobile.

As this invention may be embodied in several forms without departing from the spirit of essential characteristics thereof, the present examples are therefore illustrative and not restrictive, since the scope of the invention is defined by the appended claims rather than by the description preceding them, and all changes that fall within meets and bounds of the claims, or equivalence of such meets and bounds are therefore intended to embraced by the claims.

Claims

1. A die casting method characterized by that primary crystal of molten metal (1A) is substantially granulated in a casting sleeve so as to form a semi-molten status, and is filled into die cavity (6) under pressure, and solidified.

2. A die casting method characterized by comprising the following processes:

   (a) process to melt metal and to control the temperature at a temperature near liquid phase line,
   (b) process to cast said molten metal (1A) and then to move said molten metal into a casting sleeve (2), and lower the temperature of said molten metal in said casting sleeve from a temperature near liquid phase line to a specified temperature lower than liquid phase line and higher than solid phase line or eutectic line at a specified cooling speed, and granulate primary crystal of molten metal substantially so as to form a semi-molten status (1B),
   (c) process to fill the semi-molten metal (1B) in said casting sleeve (2) having granulated primary crystal into a die cavity (6) under pressure, and
   (d) process to solidify said molten metal (1B) filled into said die cavity (6) under pressure.

3. A die casting method set forth in claim 1, wherein at least part of inner cylinder of the casting sleeve (22) is formed by low thermal conducting material.

4. A die casting method set forth in claim 2, wherein at least part of inner cylinder of the casting sleeve (22) is formed by low thermal conducting material.

5. A die casting method set forth in claim 1, wherein molten metal (1B) in said casting sleeve (2) is heated and kept warm by electro-magnetic stirring, and then filled under pressure into said die cavity.

6. A die casting method set forth in claim 2, wherein molten metal in said casting sleeve (2) is heated and kept warm by electro-magnetic stirring, and then filled under pressure into said die cavity (6).

7. A die casting method set forth in claim 3, wherein molten metal in said casting sleeve (2) is heated and kept warm by electro-magnetic stirring, and then filled under pressure into said die cavity (6).

8. A die casting method set forth in claim 4, wherein molten metal in said casting sleeve (2) is heated and kept warm by electro-magnetic stirring, and then filled under pressure into said die cavity (6).

9. A die casting method set forth in any one of claims 1-8, wherein several electroconducting materials (9) are disposed on at least part of the inner cylinder of the casting sleeve (22) so as to generate a magnetic field by the induction coil of the outside of said electroconducting materials (9), and the temperature of said molten metal in the casting sleeve (22) is lowered from a temperature near liquid phase line to a specified temperature lower than liquid phase line and higher than solid phase line or eutectic line, and the molten metal is heated or kept warm and stirred, then filled into said die cavity (6) under pressure.

10. A die casting method set forth in claim 1, wherein the inside of said die cavity (6) is made into decompressed atmosphere and/or inert gas atmosphere at least when semi-molten metal (1B) is being filled into said die cavity (6).

11. A die casting method set forth in claim 2, wherein the inside of said die cavity (6) is made into decompressed atmosphere and/or inert gas atmosphere at least when semi-molten metal is being filled into said die cavity (6).

12. A die casting method set forth in claim 3, wherein the inside of said die cavity (6) is made into decompressed atmosphere and/or inert gas atmosphere at least when semi-molten metal is being filled into said die cavity (6).

13. A die casting method set forth in claim 4, wherein the inside of said die cavity (6) is made into decompressed atmosphere and/or inert gas atmosphere at least when semi-molten metal is being filled into said die cavity (6).

14. A die casting method set forth in claim 5, wherein the inside of said die cavity (6) is made into decompressed atmosphere and/or inert gas atmosphere at least when semi-molten metal is being filled into said die cavity (6).

15. A die casting method set forth in claim 6, wherein the inside of said die cavity (6) is made into decompressed atmosphere and/or inert gas atmosphere at least when semi-molten metal is being filled into said die cavity (6).

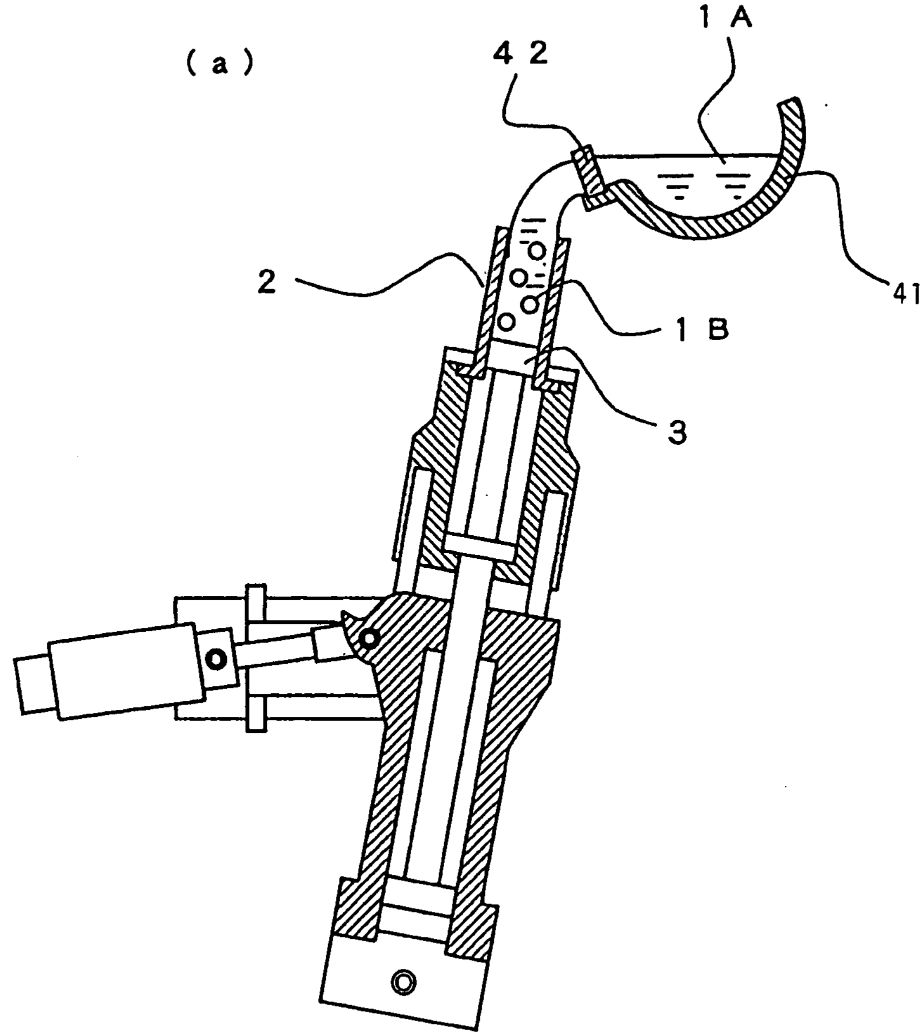
16. A die casting method set forth in claim 7, wherein the inside of said die cavity (6) is made into decompressed atmosphere and/or inert gas atmosphere at least when semi-molten metal is being filled into said die cavity (6).

17. A die casting method set forth in claim 8, wherein the inside of said die cavity (6) is made into decompressed atmosphere and/or inert gas atmosphere at least when semi-molten metal is being filled into said die cavity (6).

18. A die casting method set forth in any one of claims 1-8, 10-17, wherein the inside of said casting sleeve (2; 22) is made into inert gas atmosphere.

Fig. 1

(a)



(b)

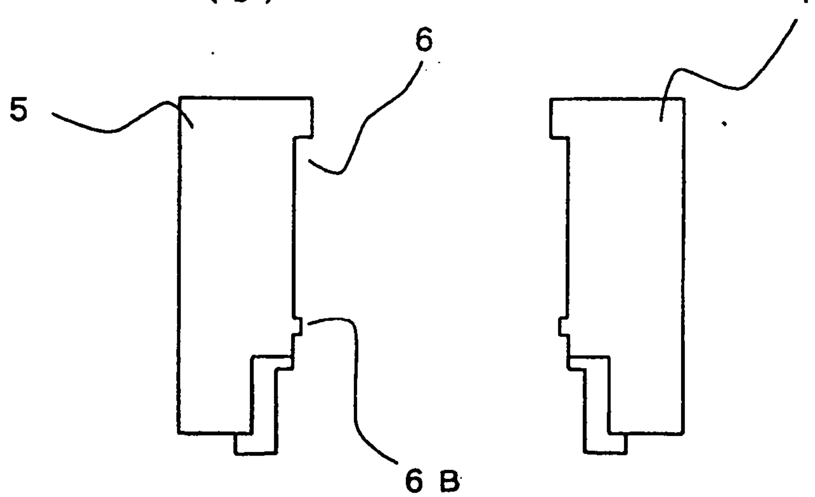


Fig. 2

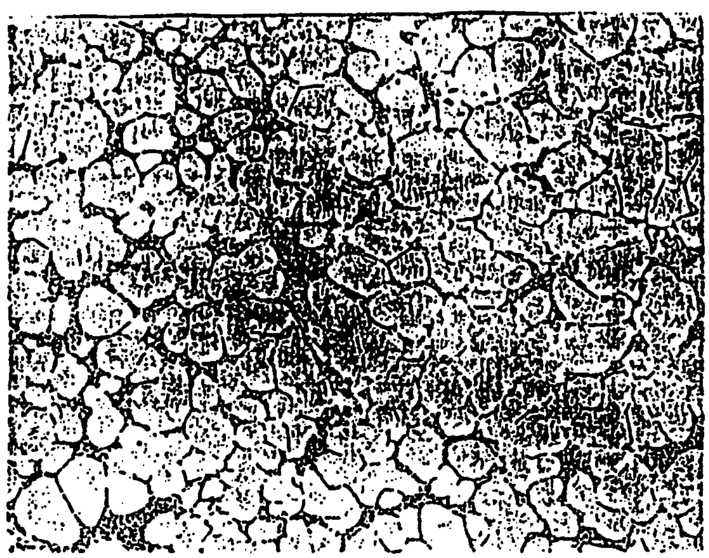


Fig. 3

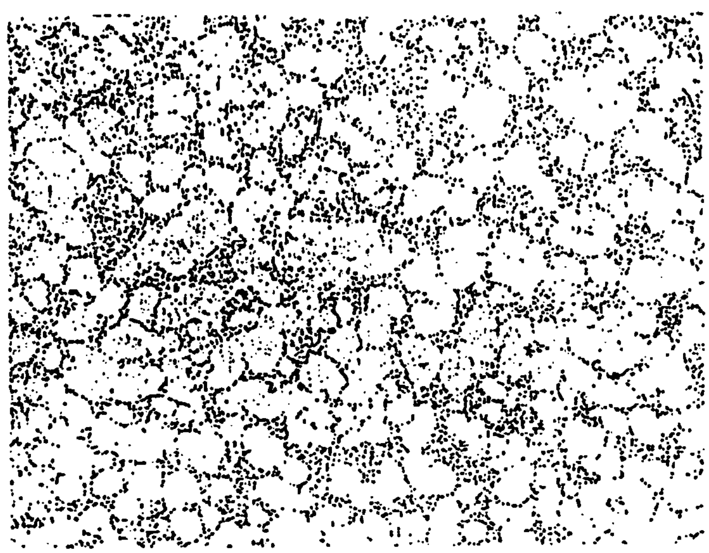


Fig. 4

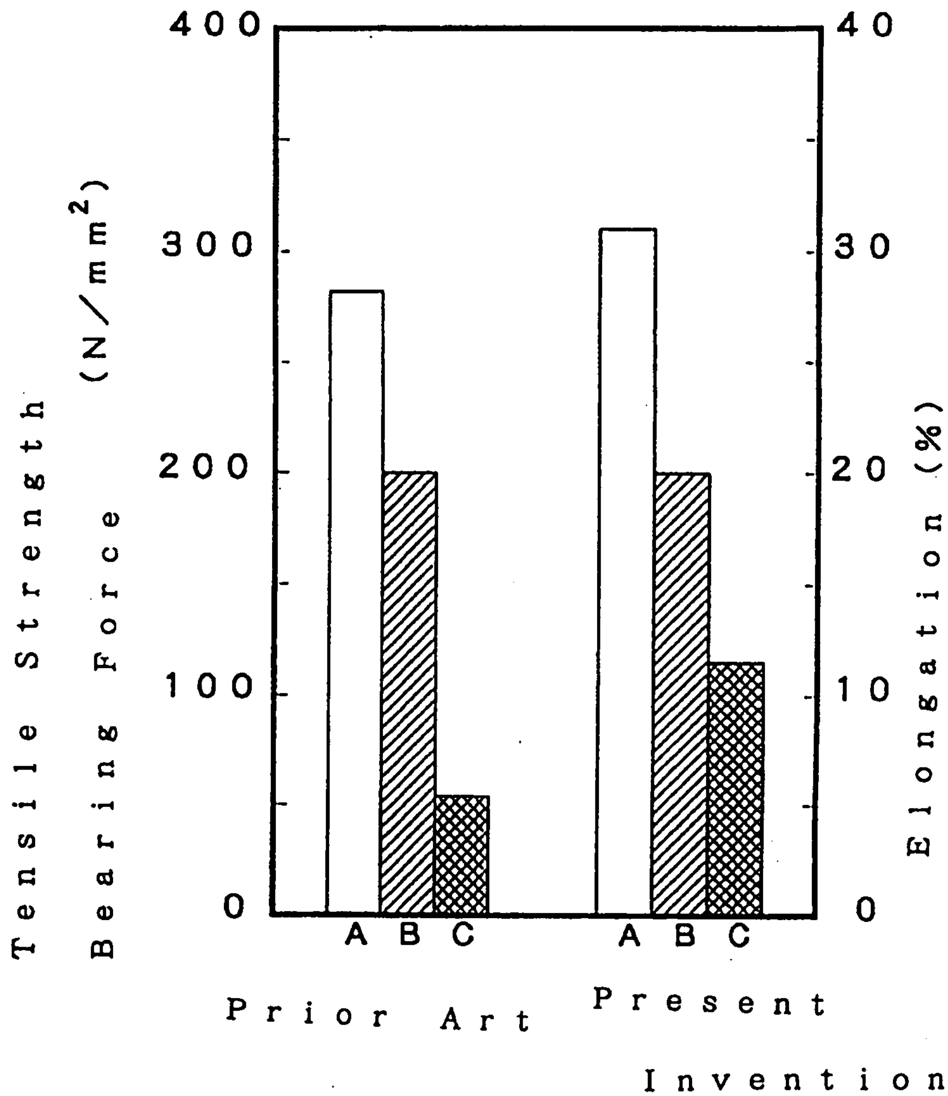

400
300
200
100
0
40
30
20
10
0
Tensile Strength
Bearing Force
(N/mm²)
Elongation (%)
A B C
A B C
Prior Art
Present Invention

Fig. 5

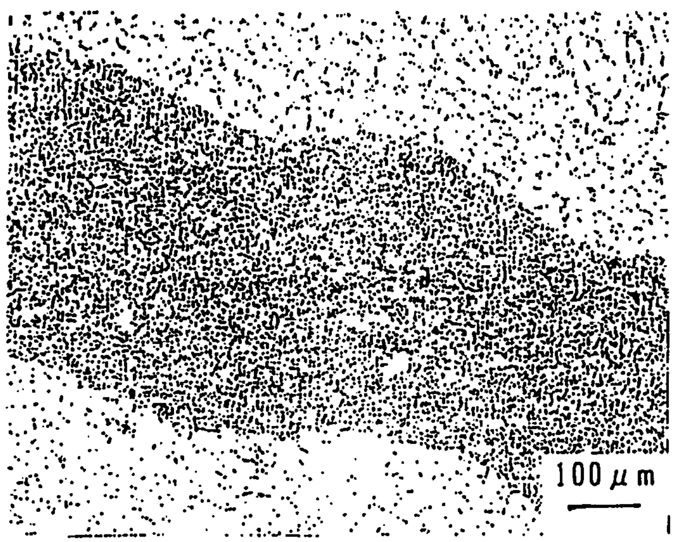


Fig. 6

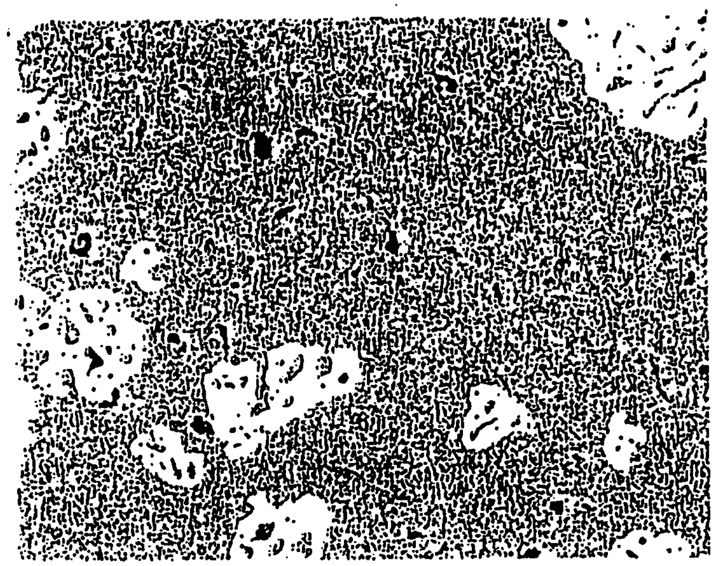


Fig. 7

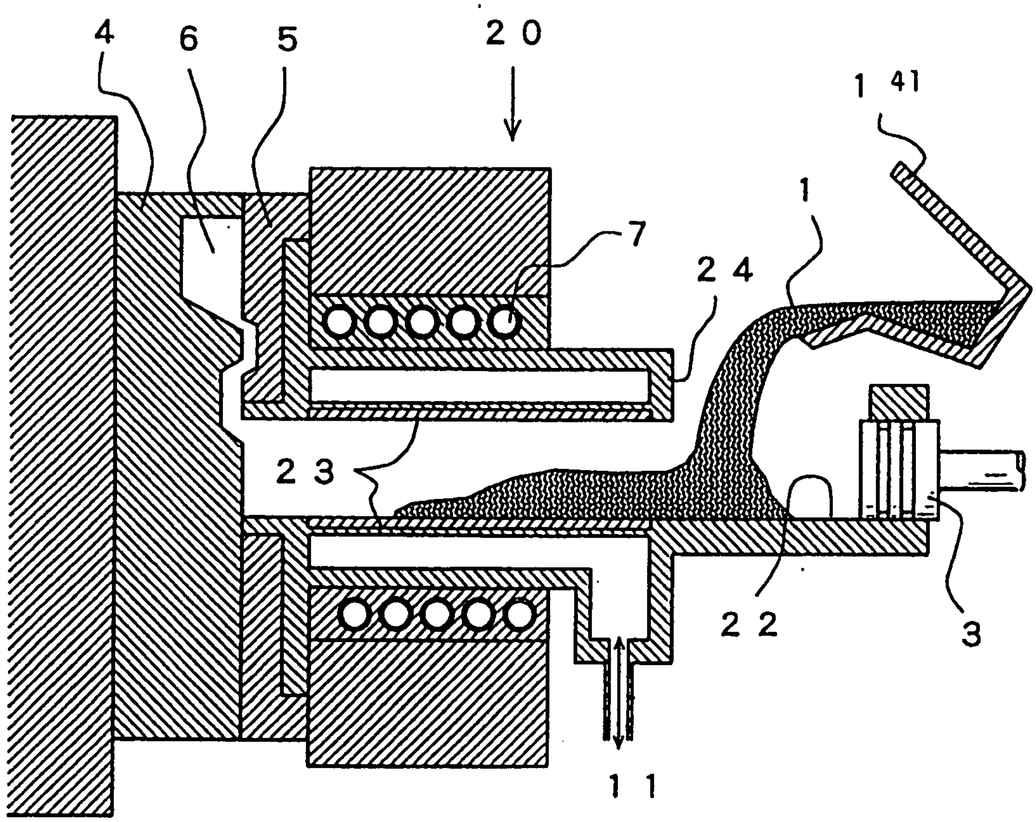


Fig. 8

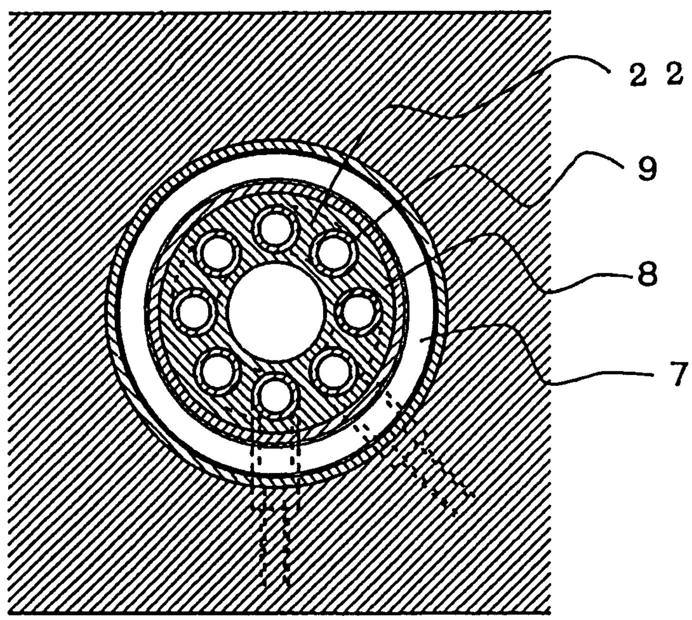


Fig. 9

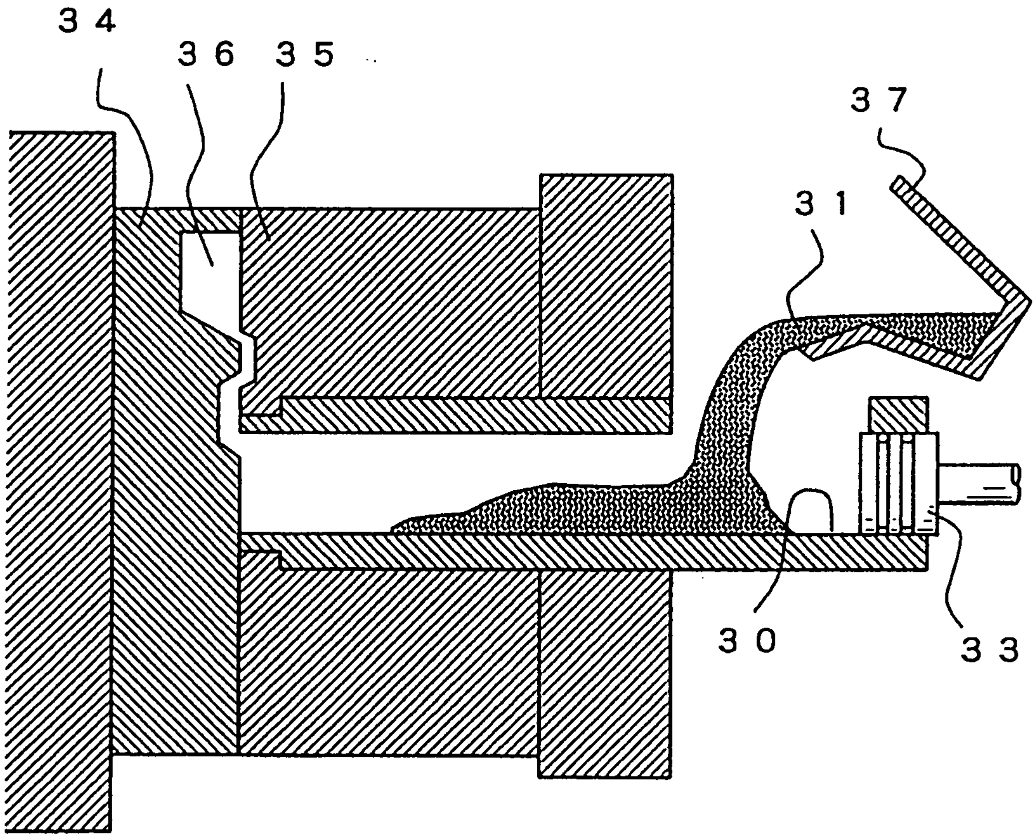


Fig. 10

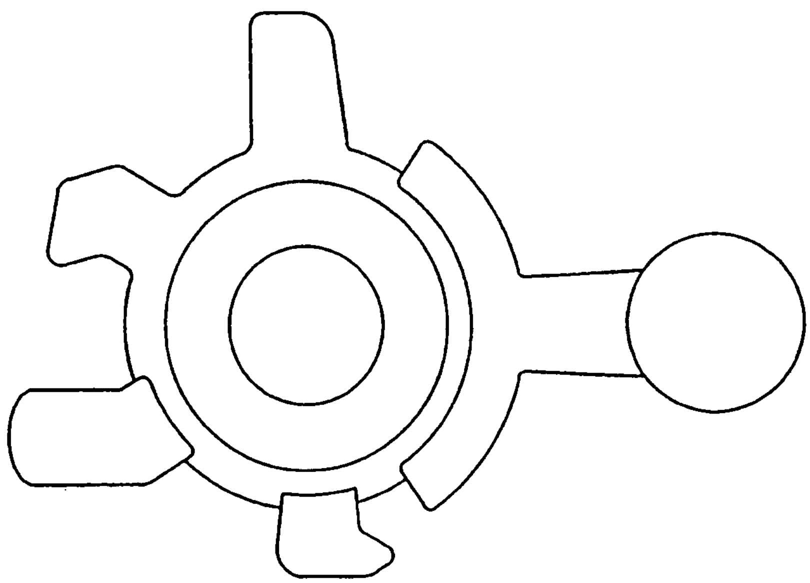
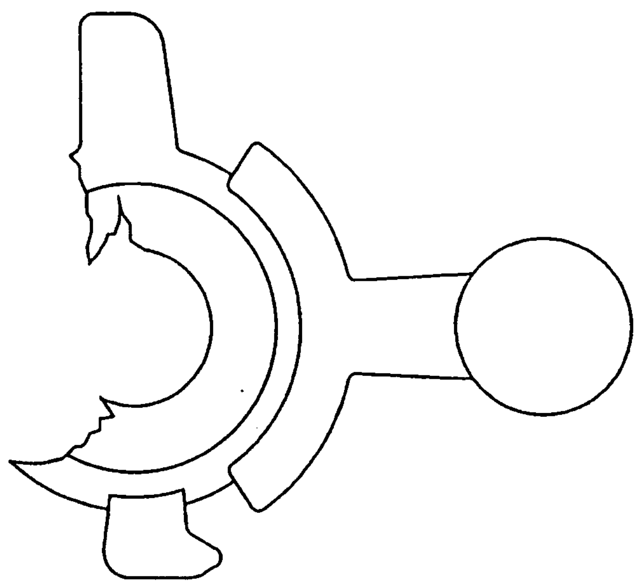


Fig. 11



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 10 4525

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	WO-A-92 13662 (TRANSVALOR SA) 20 August 1992 * claims; figure 9 *	1,2	B22D17/00
X	PATENT ABSTRACTS OF JAPAN vol. 013, no. 434 (M-875), 28 September 1989 & JP-A-01 166874 (AKIO NAKANO), 30 June 1989, * abstract *	1	
X	PATENT ABSTRACTS OF JAPAN vol. 95, no. 002 & JP-A-07 051827 (JAPAN STEEL WORKS LTD:THE), 28 February 1995, * abstract *	1	
A	PATENT ABSTRACTS OF JAPAN vol. 014, no. 110 (M-0943), 28 February 1990 & JP-A-01 313164 (NKK CORP), 18 December 1989, * abstract *	1,2	TECHNICAL FIELDS SEARCHED (Int.Cl.6) B22D
D,A	PATENT ABSTRACTS OF JAPAN vol. 009, no. 319 (M-439), 14 December 1985 & JP-A-60 152358 (AKEBONO BRAKE KOGYO KK), 10 August 1985, * abstract *	1,2	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	24 June 1996	WOUDENBERG, S

CATEGORY OF CITED DOCUMENTS

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